ME-83-03

Detecting Deterioration in Asphalt-Covered Bridge Decks

– A Demonstration Project

F. B. Holt
Research Technical Officer

Published by:

The Research and Development Branch
Ontario Ministry of Transportation and Communications
Hon. James W. Snow, Minister
H. F. Gilbert, Deputy Minister

Published without prejudice
as to the application of the finding.
Crown copyright reserved; however, this
document may be reproduced for non-commercial
purposes with attribution to the Ministry.

For additional copies write:
The Editor, Technical Publications
Ministry of Transportation and Communications
1201 Wilson Avenue
Downsview, Ontario
M3M 1J8

June 1983

TABLE OF CONTENTS

	PAGE
1/ INTRODUCTION	1
2/ SITES	2
3/ TEST PROCEDURES	3
3.1/ Thermal Infrared Scanning	3
3.2/ Radar	3
4/ TEST RESULTS	4
4.1/ Hwy 25 -- Black Creek Bridge	4
4.1.1/ Infrared Results	4
4.1.2/ Radar Results	4
4.1.3/ Exposed Deck	4
4.2/ Hwy 401 -- Humber River Bridge	4
4.2.1/ Infrared Results	5
4.2.2/ Radar Results.	5
4.2.3/ Exposed Deck	6
4.3/ QEW -- Welland River Bridge	6
4.3.1/ Infrared Results	6
4.3.2/ Radar Results.	7
4.3.3/ Exposed Deck	7
4.4/ Hemlock Creek -- Regional Road 3 -- Selkirk	7
4.4.1/ Infrared Results	8
4.4.2/ Radar Results.	8
4.4.3.1/ Exposed Deck	9
4.5/ Conestoga River -- Regional Road 22	9
4.5.1/ Infrared Results	9
4.5.2/ Radar Results	9
4.5.3/ Exposed Deck	9

PAGE

5/ OBSERVATIONS 11

6/ DATA REDUCTION 13

7/ DISCUSSION 14

8/ CONCLUSIONS 15

9/ RECOMMENDATIONS 16

10/ REFERENCES 17

TABLES

1/ Test Conditions for Infrared Scanning..... 18

LIST OF FIGURES

1/ Thermal Scanner Mounted on Boom Over Van..... 19

2/ Cart-Mounted Radar System..... 19

3/ Black Creek Bridge..... 20

4/ Humber River -- Thermal, Radar, and Existing Surveys..... 21

5/ Welland River -- Thermal and Radar Surveys, Core Locations..... 22

6/ Hemlock Creek -- Thermal and Radar Surveys..... 23

7/ Hemlock Creek -- Mottled Thermal Image of Debonded Area..... 24

8/ Conestoga River -- After Wearing Course Removal..... 24

1/ INTRODUCTION

Project 22131 was initiated to investigate the feasibility of using infrared thermography and ground penetrating radar as operational tools in bridge deck evaluation. Five bridges on the 1982 construction program were tested prior to construction work.

The results of these inspections were compared to observations made after the asphalt wearing courses were removed. This report examines the results as well as the problems encountered. Solutions for most of these problems are also reported.

2/ SITES

The following sites were tested:

Hwy 25	Black Creek bridge	Contract 81-09	
Hwy 401	Humber River bridge	Eastbound core	Contract 81-108
QEW	Welland River bridge	Northbound passing lane	
Regional Road 3	Hemlock Creek bridge	Regional Municipality of Haldimand Norfolk	
Regional Road 22	Conestoga River bridge	Regional Municipality of Waterloo	

3/ TEST PROCEDURES

Each bridge was initially scanned with infrared thermography. If extensive deterioration or different types of deterioration were found, the bridge was also scanned with the radar system. Detailed descriptions of the thermal scanner and the radar system are found elsewhere [1, 2]. The test conditions for each structure are listed in Table 1.

3.1/ Thermal Infrared Scanning

The thermal scanning was carried out using an AGA 720 infrared scanner with a 12° lens. The system incorporates on-line video recording using a Panasonic NV8410 video recorder. The camera was mounted on a boom truck and driven over the deck at a constant speed. The camera had an elevation of approximately 4.5 m above the deck surface (Figure 1). A voice recording was made during field testing to assist in interpreting the data. In the laboratory the video tape was converted from a non-standard scan rate to a standard TV rate using a Scan converter 700.

3.2/ Radar

As in past work, the radar system was cart-mounted and pushed along grid lines on the deck (Figure 2). The data was collected in a continuous fashion with a distance pulse from a "fifth" wheel also being recorded on magnetic tape. The grid spacing on the test decks was nominally one metre with the grid lines parallel to the curb.

Data analysis was carried out by the Penetradar Corporation using a newly devised computer program, called the "manual disturbance entry method [3]. A microcomputer was used to monitor the position of the radar. The operator was responsible for signalling the computer when a disturbance was viewed on a monitor oscilliscope. Then the computer produces a hardcopy plot of the disturbances within the bridge deck.

4/ TEST RESULTS

The test conditions and results are summarized in Table 1.

4.1/ Hwy 25 -- Black Creek Bridge

The Black Creek bridge is a bow string arch constructed in 1931. The deck, with an area of 6.3 m x 36.7 m had an asphalt wearing course approximately 100 mm thick. The asphalt was in fair condition with surface cracking throughout the wearing course (Figure 3).

4.1.1/ Infrared Results

Initially, the arches of this structure (Figure 3) cast shadows over the deck surface, necessitating extended testing on the structure. Total test time on the structure was 2 h and 30 min. No delaminated (hot) areas were detected, however the pavement cracking may have masked isolated areas of deterioration.

Some indications of isolated scaling were found in the curb areas, and no debonded areas were detected.

4.1.2/ Radar Results

With very little deterioration evident in the infrared scanning, the decision was made not to test with the radar system.

4.1.3/ Exposed Deck

A number of small (less than 0.25 m^2) delaminations were found when the asphalt was removed. Some moderate scaling, less than 4 mm in depth, was found in the deck areas adjacent to the curbs.

4.2/ Hwy 401 -- Humber River Bridge

The Humber River bridge is a thin slab on AASHTO beam construction built in 1954 and expanded in 1964. The deck measures 92 m in length. The driving lane (DL) and DL shoulder, and the passing lane (PL) and PL

shoulder of the centre core eastbound were tested. The asphalt surface was uncracked and there were a number of small patches resulting from conventional condition survey work.

4.2.1/ Infrared Results

A large number of delaminations were found in the passing lane. Span 1 (from the west) had a large number of small delaminations on the south side of the lane. Span 3 contained a number of small delaminations near the north edge of the lane. Delaminations were also found in the concrete curb area.

The driving lane shoulder was clear except for one small area which appeared extremely "hot". It was assumed that this area, due to its "hot" appearance, was a debonded area rather than a delaminated area.

The driving lane exhibited a large "cooler" area over to the length of the bridge. The area was approximately a metre and a half wide and approximately 0.5°C cooler than the surrounding deck. A few small hot areas were found, ranging in size from 15 cm to 0.5 m.

No testing was carried out in the centre lane due to extremely high traffic volumes.

Figure 4 shows the "hot" areas detected by the infrared scanner with the actual deterioration and the radar data. Great difficulty was encountered in transferring the video-tape information to the mylar plans due to a lack of information regarding distance and location .

Overall, infrared thermography identified 6.5% of the deck as being deteriorated. This compares with 8.6% of the deck area which was identified as deteriorated when the asphalt wearing course was removed.

4.2.2/ Radar Results

The data analysis system developed by Penetradar showed that 17% of the driving lane and shoulder were deteriorated. The passing lane was found to be 24% deteriorated. The computer system plots the areas of

deterioration as discrete points 0.50 m apart along the grid line. This data was overlayed on Figure 4 to assess the number of points identified correctly. Of 396 points identified, only 49 were over areas found to be deteriorated, giving an accuracy of 12.4%. The radar analysis indicated that the asphalt thickness varied from about 70 mm in passes 1 and 2 to almost 225 mm in passes 3, 4, and 5.

4.2.3/ Exposed Deck

The exposed deck showed evidence of some delamination and minor scaling; giving a total estimated area of 9.5%. It was difficult to determine which areas may have been debonded due to the procedure used to take off the asphalt. It should be noted that the radar analysis correctly identified the location of variations in the asphalt thickness.

The large "cool" area identified with thermography was an area of extremely thick asphalt (≈ 200 mm+) over the area where the bridge was in widened in 1964.

4.3/ QEW -- Welland River Bridge

The Welland River Bridge is a slab on beam construction built in 1940. The area tested was the passing lane northbound. The area measured 140 m long by 5 m wide. The asphalt wearing course was heavily cracked and patched. Figure 5 shows the thermal and radar results, and the locations of the cores taken.

4.3.1/ Infrared Results

The structure was tested during a repair closure. This created some difficulties due to vehicles and materials occupying some of the lane area. The asphalt was extensively cracked with a large number of patches.

From the south, span 1 showed only one or two "warm" areas less than 0.5 m in diameter. Span 2 had a large number of "hot" areas covering the majority of the lane. This span was under repair due to a "punch out" in the bridge deck. Spans 3 and 4 had a large number of "hot" areas throughout the area. Span 5 was similar to span 1, with a small number of isolated "hot" areas.

Where hot areas were adjacent to cracked or patched areas, some difficulties were encountered in interpreting the extent of the deteriorated areas. Some hot areas appeared mottled, indicating scaling and/or debonding, however these were not well defined.

4.3.2/ Radar Results

A total of 264 points were designated as deteriorated. Of these, 10 coincided with areas determined by the infrared scanner as being deteriorated. The computer evaluation, which concentrated on spans 1, 2, and 3, indicated that 17% of the first 100 m of the lane was deteriorated. In the last 40 m, the radar system showed 38% to be deteriorated, with the deterioration equally distributed between spans 4 and 5.

4.3.3/ Exposed Deck

The deck was not exposed during the project. However, cores were taken in a number of areas, including areas presumed to be solid and areas identified as suspect by either the infrared scanning or radar, or both.

The cores taken in solid areas were solid with a good bond. Four cores were taken in areas identified by radar. In three cases, steel was encountered and the core was in good condition. In one case the core had a multiple delamination and no bond between the asphalt and the concrete.

Four cores were taken in areas identified by thermography. In two of these there was no delamination, but there was no bond between the asphalt and the concrete. The other two cores exhibited delamination of the concrete at the level of the reinforcing steel.

4.4/ Hemlock Creek -- Regional Road 3 -- Selkirk

Hemlock Creek is a two span rigid frame structure built in 1934. The bridge measures 8 by 33 m. The surface was in a deteriorated condition; the asphalt wearing course was heavily patched and missing within 20 cm of the curb. The exposed concrete surface and adjacent curbs were heavily scaled. When struck with a chain, the majority (more than 70%) of the

asphalt-covered area sounded hollow, indicating debonding of the wearing course.

4.4.1/ Infrared Results

Difficulties were encountered in interpreting the infrared data. Only one large distinct hot area was detected in the north-east corner of the deck. The remainder of the deck exhibited a mottled grey-white appearance as seen in Figure 6.

It can be concluded that this was due to two factors:

a) the extensive cracking and patching found on the wearing course; and
b) the debonding of the wearing course.

4.4.2/ Radar Results

Computer analysis indicated only 1% of the deck was delaminated. The radar system did pick out the single well-defined "hot" spot found with the thermal system.

Of concern is the lack of deterioration indicated by the radar analysis. With so much of the bridge apparently debonded, it was felt that a larger percentage of deterioration would have been found. There are two feasible reasons for this problem.

First, the cart-mounted system was picking up "noise" from the vibrations induced to the cart by the rough surface. This may have caused the signal to be less than ideal for interpretation.

Secondly, the radar analysis procedure is at best raw analysis. The procedure was untried and requires some refinement.

4.4.3/ Exposed Deck

This deck was not repaired during the project due to lack of funds. Repairs are planned for the 1983/84 construction season, at which time further investigations of the concrete condition will be carried out.

4.5/ Conestoga River -- Regional Road 22

The Conestoga River bridge is a continuous four span, thin slab on beam construction built in 1958. The deck area is 10 m by 106 m. Figure 7 shows the deck condition found after removal of the wearing course.

The wearing course was in fair condition, with some deterioration of the asphalt adjacent to the curbs exposing heavily scaled concrete. Moderate longitudinal cracking of the wearing course was visible throughout the deck area. When struck with a chain, spans 2 and 3 were found to have a hollow ring indicating debonding of the wearing course.

4.5.1/ Infrared Results

Spans 1 and 4 did not exhibit any significant hot areas other than those adjacent to the curbs where scaled concrete was visible. Spans 2 and 3 exhibited the mottled grey and white in the scanner image that was apparent on the Hemlock crack structure. Again, the hollow ring and the mottled appearance indicate debonding of the wearing course. Some isolated delaminations "hot" areas, were found in spans 2 and 3, however these could have been due to moisture between the wearing course and the concrete.

4.5.2/ Radar Results

No radar tests were carried out on this structure due to its location and the timing of repairs.

4.5.3/ Exposed Deck

Extensive scaling was found throughout spans 2 and 3 (Figure 8). Spans 1 and 2 were generally sound, with scaling adjacent to curbs and joints.

No delaminations were found although surface conditions did not permit accurate determinations with a chain. Scaling near the curbs and joints was found to be approximately 25 mm deep while the scaling in other areas ranged from 5 to 12 mm deep.

5/ OBSERVATIONS

During testing, a number of observations were made on the test procedures;

- Delaminations under most conditions appear as white or "hot" areas on the scanner screen, the same as was found at the Bancroft Papineau Creek test site [1].

- Large areas of debonding and/or scaling appear as mottled grey tones on the scanner screen. It was not clear whether the two must occur together to achieve this effect, or whether their appearance is the same when they are separate. Conestoga and Hemlock had these effects in tandem.

- Wheel track polishing creates a "blooming" of the image on the scanner. This can be mistakenly interpreted as delaminated areas. Observation of the pavement surface condition can eliminate this problem.

- Large amounts of patching, as was seen at Welland, can make interpretation of the scanner image very difficult.

- Deterioration of the asphalt wearing course adjacent to the curbs, as seen at Hemlock and Conestoga, causes the "automatic gain control" circuitry of the AGA Thermovision system to override the deck image, resulting in poor video images. Care should be taken in the positioning of the scanner in relation to the curb to eliminate this problem.

- Moisture in debonded areas may cause the scanner to pick up both "hotter" or "cooler" areas on the deck, making interpretation difficult. Only field experience will assist in alleviating but not eliminating this interpretation problem.

- The scanner must be mounted on a stable platform to decrease or eliminate movement. This will assist in producing the sharpest possible images.

- Consistency of vehicle speed in traversing the bridge deck will allow better definition of the thermal areas on the deck. A maximum of 10 km/h appears to be optimal.

- The use of a cart-mounted system for the radar tests is inadequate. The cart wheels induce "noise" in the signal, making interpretation of the radar waveform more difficult.

- The radar waveforms in debonded, delaminated and scaled areas are similar to those found at the Papineau Creek test site [1].

- Attempts were made to assess the exposed deck condition during contract work. This was found to be difficult due to the lack of a grid system for location and the need to avoid delaying the contractor during his work.

6/ DATA REDUCTION

The following observations were encountered in the data reduction phase of the program:

- The use of the Scan Converter 700 on the AGA thermal scanner assists in viewing the thermal images. Interpretation of the image is enhanced, although the nature of the converted image is more geometric due to its computer compatability.

- The use of a voice track on the video tape of the thermal image was extremely useful in analysing the data.

- The lack of a common distance marker within both the radar and infrared data created many problems in accurately assessing the data and any interrelationship between the two.

- Putting the thermal data in a usable format is still impossible with present techniques. Interpretation on site, marking areas as you go, is presently the only accurate way of recording the scanner output. This is not only tedious but highly impractical in a mobile configuration.

- The use of the Scan Converter allows one to freeze frame the scanner video signal, which is useful if an area needs to be studied in detail.

- Present computer programming to analyse the radar signal is in fact less accurate than the procedure utilized in project 22141. The program needs refinements to produce acceptable accuracy.

7/ DISCUSSION

While this project was not able to produce a functional data collection and analysis system, it did provide an opportunity to test the procedures under varied conditions. The problems of data collection, while significant at this stage, can be solved without major rebuilding of the procedures.

The problems of data reduction also appear to be surmountable with the technology presently available. Investigations carried out in the laboratory showed that it is possible to produce continuous strip photos of the thermal scanner's video signals using a Honeywell 1856A Visarecorder.

This procedure is being used in the United States with great success. The strip photo is accurate, scaleable, and reproduceable. The use of a real life video camera to record the condition of the deck will allow the technician to eliminate spalls, wear patterns, patches and cracks while interpreting the thermal data.

The use of a single distance measuring device recorded on both the radar systems and the thermal system will allow complete integration of the data. The data would be plotted on the same grid allowing for the possible calculation of quantities rather than just areal extent.

8/ CONCLUSIONS

- It is feasible to collect data in a mobile non-contact fashion using radar and infrared scanning.

- The thermal and radar characteristic patterns found at the Papineau Creek site, are applicable to other structures.

- Data reduction of the thermal scanner imagery can be accomplished by using hard copy production procedures and technology in use in other agencies.

- The reduction of radar data to an accurate usable format requires a major effort in the development of a computer program to analyse the radar wave form.

- The radar system is capable of determining the thickness of asphalt overlays accurately.

9/ RECOMMENDATIONS

The following recommendations are made:

- A project be initiated to develop the necessary computer software to analyse the radar wave form accurately.

- The Ministry purchase a Penetradar system to be used in a production prototype for the determination of asphalt overlay thickness, and the location and depth of various forms of deterioration.

- A hard copy production system be purchased to enable the thermal data to be utilized to its fullest extent.

10/ REFERENCES

[1] Manning, D.G., Holt, F.B. "Detecting Deterioration in Asphalt Covered Bridge Decks", TRR No. 899 (1983) pp. 10-20.

[2] Alongi, A.V., Cantor, T.R., Kneeter, C.P. and Alongi, A. Jr., "Concrete Evaluation By Radar -- Theoretical Analysis", TRR No. 853 (1982) pp.31-37.

[3] Alongi, A. Jr., Internal Consultant report, "Radar Inspection and Mapping of Three Bridge Decks", 1982.

Table 1/ Test Conditions for Infrared Scanning

SITE	TEST CONDITIONS				
	WIND Km/h	AIR TEMPERATURE (Shaded) °C	DECK SURFACE TEMPERATURE °C	CLOUD COVER %	RELATIVE HUMIDITY %
Black Creek HWY 25 Contract 81-09	9 to 12 km/h	21°C	27.7°C	10-15% Increasing to 80%	44%
Humber River HWY 401 EB. Core Contract 81-108	10-15 km/h Gusty	24°C	29.3°C	10 to 0%	50%
Welland River Q.E.W. N.B. PL	25-30 km/h	32°C	39.2°C	25%	55%
Hemlock Creek Regional Rd 3 Selkirk Reg. Mun. of Hald. Norfolk	25-30 km/h	31.5°C	37.3°C	15%	55%
Conestoga River Regional Rd. 22 Reg. Mun. of Waterloo	10 km/h Gusty	22.5°C	27.5°C	0-35% Variable	40%

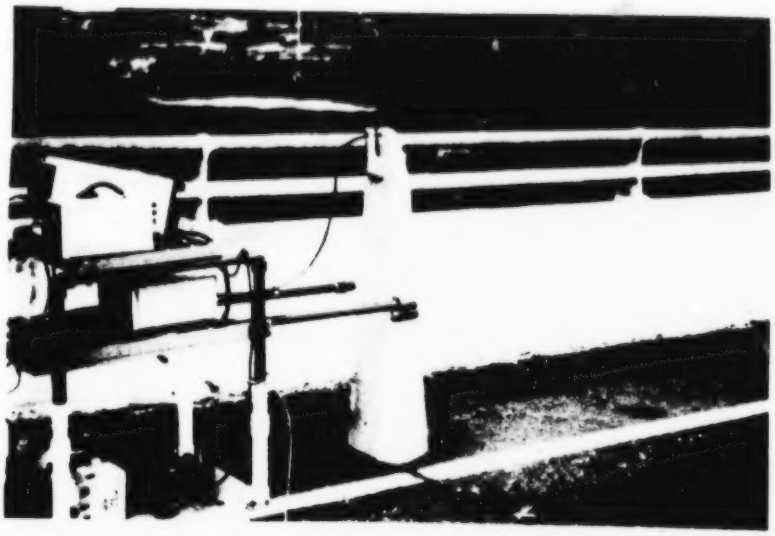
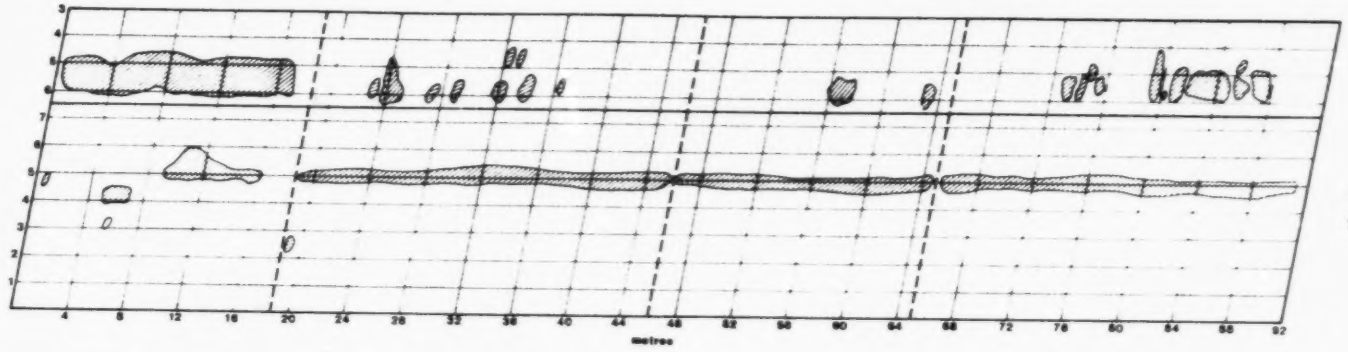
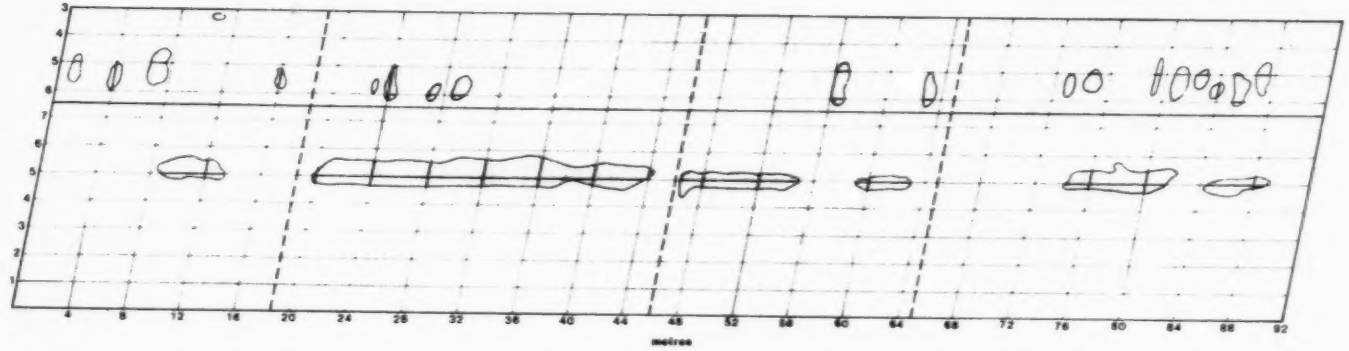


Figure 1 / Thermal Scanner Mounted on Boom Over Van

Figure 2 / Cart-Mounted Radar System

Figure 3 / Black Creek Bridge





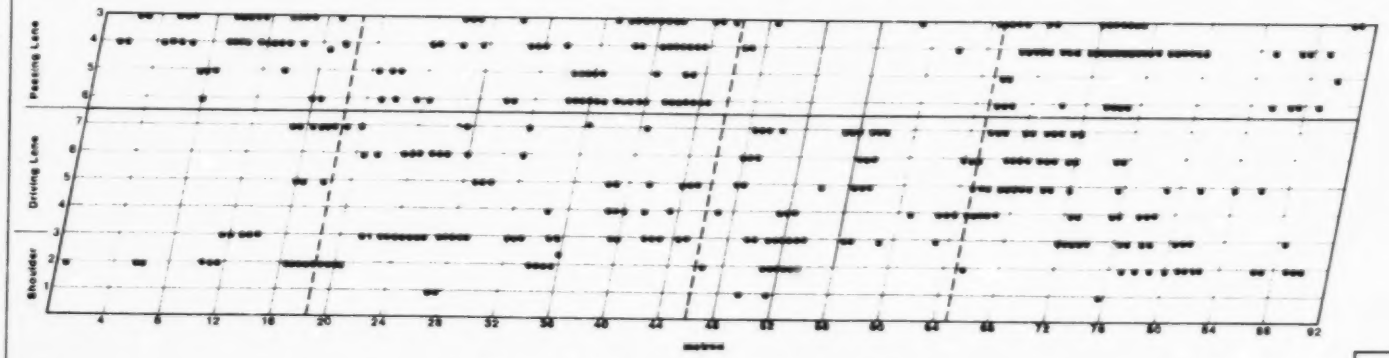


Figure 4 / Humber River - Thermal, Radar, and Existing Surveys

NO.	DESCRIPTION	DATE	BY
REVISIONS			

Ministry of Transportation and Communications — Ontario

SCALE	
DATE	
DRAWN	
TRACED	
CHECKED	
TOLERANCES	

Hwy. 401 Eastbound Core
Humber River Bridge
July, 1982

DRAWING NUMBER
OF
PROJECT NUMBER

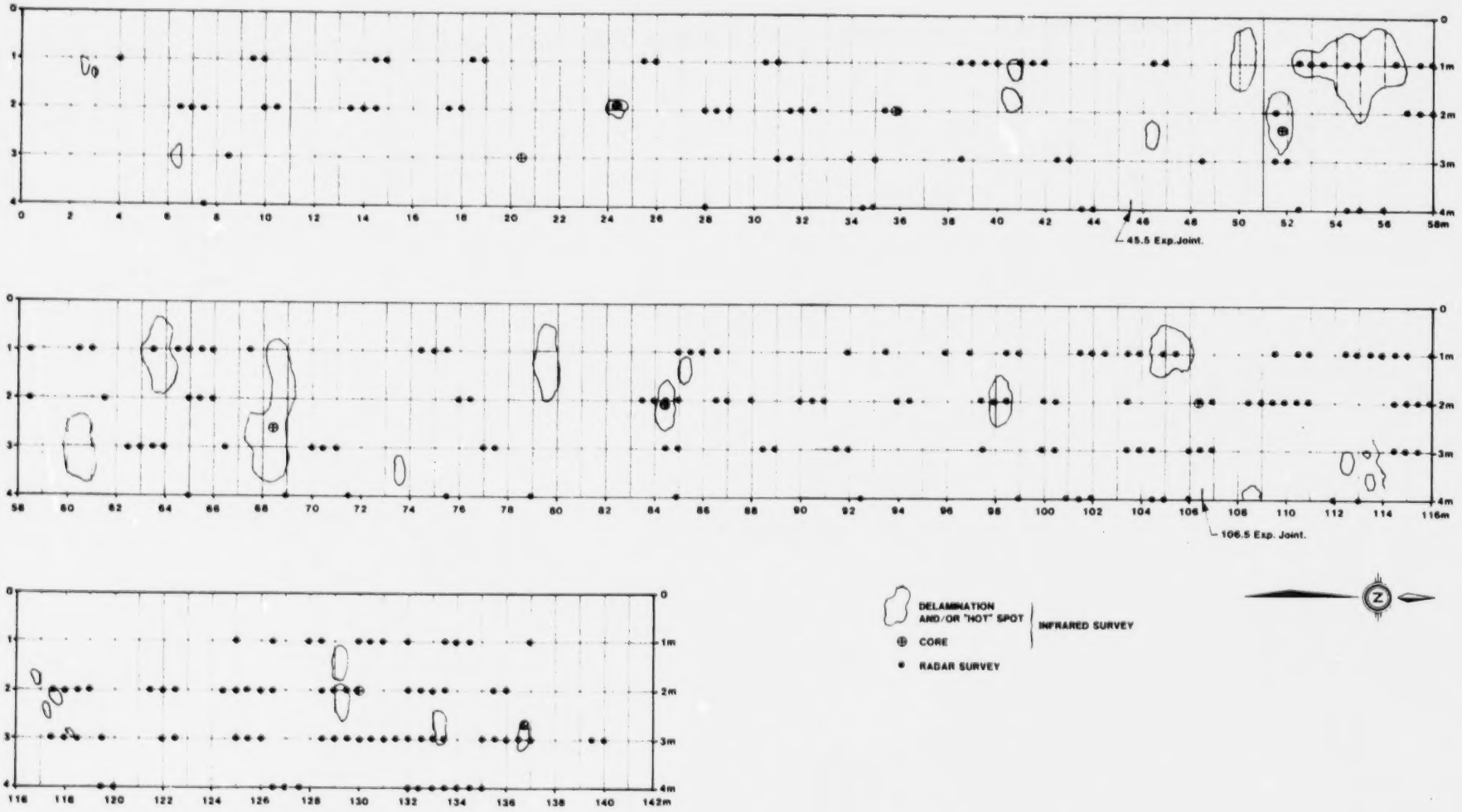
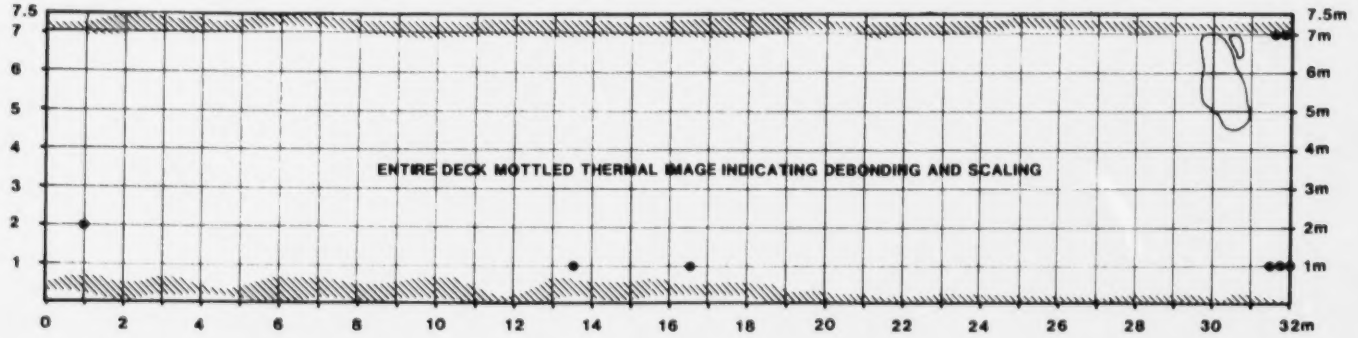


Figure 5 / Welland River - Thermal and Radar Surveys, Core Locations

MATERIAL LIST			
ITEM NO	NO REQ'D	DESCRIPTION	DRAWING NUMBER



SCALING, ASPHALT MISSING

DELAMINATION
Infrared Survey

DETERIORATION
Radar Survey

Figure 6 / Hemlock Creek - Thermal and Radar Survey.

LET	DESCRIPTION	DATE	BY

REVISIONS

Ontario Ministry of Transportation and Communications	ENGINEERING RESEARCH AND DEVELOPMENT BRANCH	SCALE		TOLERANCES
		DATE		DECIMALS ANGLES FRACTIONS
		DRAWN		
		TRACED		
		CHECKED		

HEMLOCK CREEK BRIDGE
SELKIRK
July, 1982

DRAWING NUMBER
OF
PROJECT NUMBER

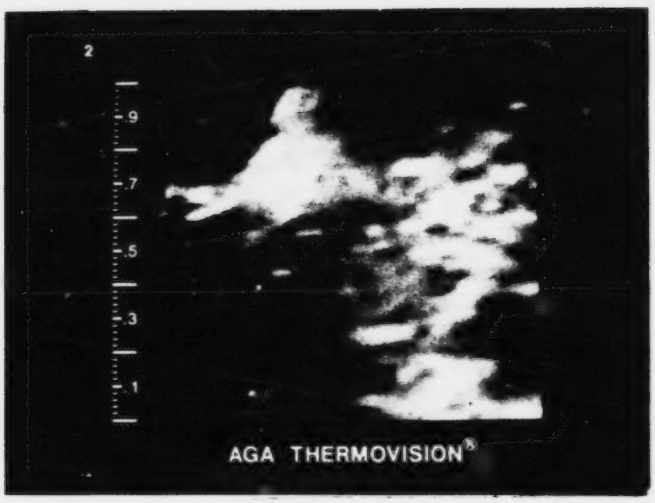


Figure 7 / Hemlock Creek - Mottled Thermal Image of Debonded Area

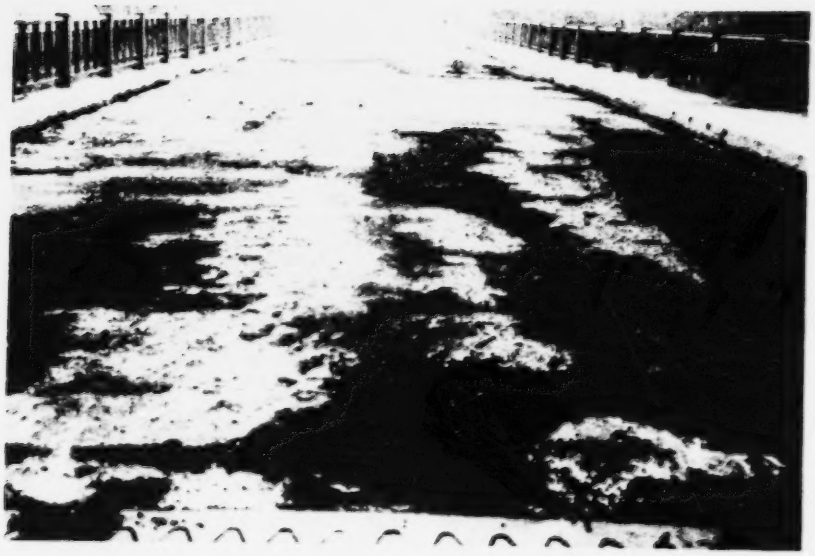


Figure 8 / Conestoga River - After Wearing Course Removal

POOR

QUALITY

ORIGINAL